Ecosystem Restoration: Winter-Run Chinook Salmon in the Sacramento River

What is this Indicator, and Why is it Important?

This indicator reports the escapement (the number of adult salmon escaping ocean harvest and inland recreational fishing and successfully returning each year to spawn) of adult winter-run Chinook salmon in the Sacramento River. The Sacramento River supports the only wild self-sustaining population of winter-run Chinook salmon in the Central Valley. Because of concerns about its status, the Sacramento River winter-run Chinook was the first anadromous salmon run listed under the Endangered Species Act in 1989. The run is now listed as endangered on both the state and federal endangered species lists and has been targeted for major restoration efforts, with the same doubling targets applied to other runs (see Technical Note and System-Wide Salmon indicator). In addition, NOAA Fisheries has established draft recovery goals for the Sacramento River winter run of an average of 10,000 spawning females over a 15-year period.

As with other runs, this indicator focuses specifically on the instream conditions that are the locus of restoration efforts and that may influence the success of four key phases of the species' survival and reproduction in the Sacramento River (see conceptual model in Figure 1). This indicator alone is clearly not sufficient to evaluate progress toward the AFRP doubling targets. Any such evaluation would necessarily include a broader range of indicators and information (see Technical Note). However, measures of instream conditions are a valuable part of this broader portfolio of indicators and can provide important insight into the progress of specific restoration actions and the effect of instream conditions on salmon populations.

What Has Happened to Affect the Indicator?

The Sacramento River winter-run has been affected by three major factors that restricted adults' access to spawning habitat, reduced the suitability of the remaining spawning habitat, and increased predation on juveniles migrating downstream. The combined action of these factors brought the run to the verge of extinction.

Because spawning occurs in late spring through mid-summer, the run is especially susceptible to elevated summer water temperatures. The completion of Shasta Dam in 1942 blocked salmon from the higher reaches of the river where they had typically spawned in cold-water habitat. While water releases from Shasta Dam, and later from Keswick Dam, recreated some cold-water habitat below the dam through the 1960s, such releases began to diminish in the 1970s as demand for water for irrigation and other purposes began to increase. As a result, elevated water temperatures below the dams could not be ameliorted to the extent they had been previously

Construction of the Red Bluff Diversion Dam in the mid 1960s created an additional barrier to adult passage lower in the river. The diversion dam's fish ladders were inadequate for complete upstream passage, particularly during the high-flow winter months. As a result, adult fish pooled below the dam, and the population experienced blockages of 25 to 40 percent, with the fish that were able to pass the dam experiencing a delay of approximately three to four weeks in reaching the spawning grounds. The diversion dam also caused an impact to the run during juveniles' downstream migration. Although the dam's underflow design permitted passage of juveniles, it disoriented the juveniles, making them much more susceptible to the predators that concentrated below the dam. As a result, juveniles at times experienced predation losses of as much as 50

percent. A further impact that brought the run to endangered status was the increased use of Shasta Dam for power production. Because the power house intakes were fairly high up on the dam, warmer water was passed downstream. The drought in the late 1980s and early 1990s resulted in a significant decline in winter-run escapement, to an estimated low of 186 spawners in 1994.

Instream restoration actions on the Sacramento River (Figure 2) have therefore focused on two major efforts, in addition to the release of hatchery fish. Through a series of management decisions, the gates at the Red Bluff Diversion Dam have been raised for increasingly longer periods of time. At present, the gates are raised to allow upstream passage of adult fish from September through May 15 each year. The other major action was the construction in the mid 1990s of a temperature-control device at Shasta Dam that allows power production to draw on the pool of cooler water in the reservoir that previously had been below the level of the power house intakes. Having dealt with these two major issues, subsequent restoration efforts then concentrated downstream of the Red Bluff Diversion Dam on land acquisitions, restoration of juvenile habitat, and the improvement of fish screens on water-diversion facilities. In addition, at the system level, export pumping in the Delta has been modified to reduce losses of juvenile winter-run Chinook salmon.

What Do the Data Show?

The data show (Figure 2) that adult winter-run Chinook escapement fluctuated through the late 1970s and then dropped precipitously in 1979. With the exception of 1988, escapement then remained extremely low until it began to increase in the late 1990s. During the 20-year period from the late 1970s through the late 1990s, escapement showed virtually none of the cycles of abundance typical of other runs of salmon in the system as a whole. In the years since significant restoration actions began in the early 1990s, escapement numbers have increased somewhat, but they remain well below levels defined for recovery. In addition to the effects of restoration actions, spawning escapement has increased since the early 1990s because of several years of improved hydrologic conditions in the Sacramento River and because of changes in ocean harvest regulations since 1995, which were designed to reduce harvest of winter-run Chinook.

The data also show that the percent of redds found above the Highway 44 Bridge (i.e., on the upper portion of the river) increased substantially beginning in 1987 and yet again beginning in 1995. On the average, the percent of the population spawning in the upper portion of the river (as reflected by the distribution of redds), is higher than at any time since data collection began in 1969. The increase in this metric may reflect the increased availability of cooler water in the upper portion of the river, due to the bypassing of power production and the construction of the temperature control device at Shasta Dam. It may also reflect adult salmon's increased access to the upper portion of the river due to management policies that kept the gates at the Red Bluff Diversion Dam open for significantly longer periods each year.

Discussion

The interaction over a number of years of a reduction in the amount of spawning habitat and the degradation of what remained (because of increased water temperatures) reduced the long-term sustainability of the population by decreasing the overall reproductive potential of the system. Similarly, the increased predator populations that concentrated below the Red Bluff Diversion Dam and losses at the export facilities in the Sacramento River delta further reduced sustainability by increasing the mortality rate of juveniles.

Restoration actions have succeeded in improving passage to upstream spawning areas, increasing the suitability of temperature regimes, and reducing predation on downstream migrating

juveniles. The timing of the increase in escapement in relation to these major restoration actions, combined with the absence of cycles of abundance from the late 1970s through the late 1990s, suggests that these actions contributed significantly to the increase in escapement after 1995. However, improved hydrologic conditions in several years since 1995, and changes in ocean harvest regulations since that time, have probably also contributed significantly to the higher escapements.

Returns of adult winter-run Chinook salmon are influenced by factors within the Sacramento River watershed, in the San Joaquin River and the delta estuary, and in the Pacific Ocean (see Figure 1). During the adult upstream migration, in the spawning areas, and during the juvenile emigration phase, access to suitable spawning habitat and the adequate conditions for survival of juveniles are key factors that can affect reproduction and survival. In the larger Sacramento River and Bay-Delta system, the timing and extent of high temperatures (especially in shaded riparian habitat), the availability of food in the river, predation, and entrainment by export pumps all could combine to affect the success of out-migration. In the Pacific Ocean, conditions related to both shorter-term events (such as El Niños) and longer-term shifts in ocean climate (such as the Pacific Decadal Oscillation) also affect overall patterns of salmon abundance. Since 1995, ocean harvest regulations have been changed to reduce harvest of winter-run Chinook. These factors can interact in complex ways, and the degree to which they become limiting, either individually or in combination, depends on their relative severity and on the state of the population at any given time.

This wide range of influences contributes to year-to-year variability in escapement and to longer-term fluctuations in population levels. Because of these sources of variability, it will take some time to determine with more certainty whether the increase in escapement in the late 1990s is part of a long-term increasing trend or merely the upward-trending portion of another cycle of abundance, such as those that have occurred in other salmon runs in the Central Valley since the 1950s.

Conceptual Model Sacramento River Winter Run

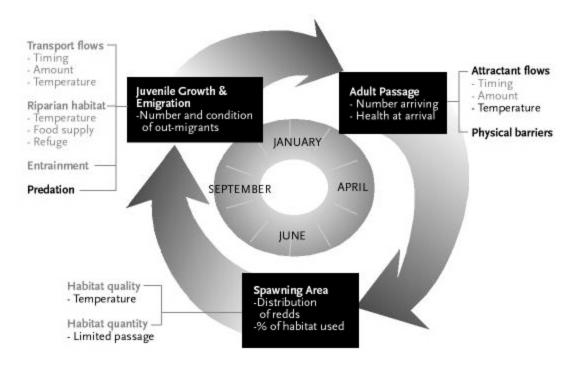


Figure 1. Conceptual model of the Sacramento River fall run, emphasizing factors and processes that operate within the Sacramento River itself. Elements in bold text have a larger influence on overall success of the run. The ocean life history phase is not included, and processes in the delta are subsumed under juvenile growth and emigration.

Sacramento River Winter Run

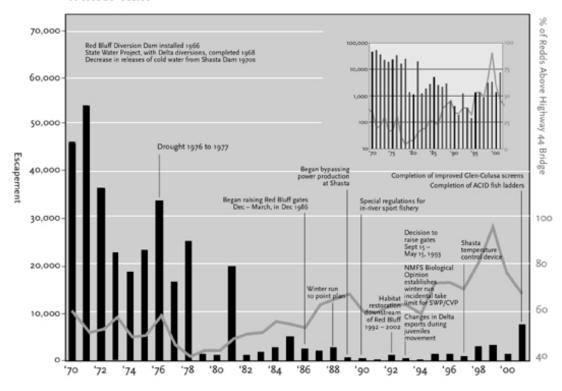


Figure 2. Long-term trend in in-river spawning escapement of Sacramento River winter-run Chinook salmon (vertical bars) shown in the context of key restoration actions and the percentage of redds each year above the Highway 44 Bridge (continuous line).

Technical Note: Winter-run Chinook Salmon on the Sacramento River

The Indicator

<u>Goal</u>: See Technical Note for the systemwide Central Valley Chinook Salmon indicator.

<u>Response Time</u>: See Technical Note for the systemwide Central Valley Chinook Salmon indicator.

The Data

<u>Data Collection</u>: Escapement data on the Sacramento River extend back to 1967. When the gates at Red Bluff Diversion Dam were closed during the entire upstream migration period prior to 1986, escapement was based on visual counts of adults using the fish ladders at the dam. After 1986, when the gates were opened for longer and longer periods of time, it was not possible to count winter-run escapement passing the dam throughout the entire run. Therefore, escapement is now estimated based on extrapolations from the period of May 15 through September when the gates are closed. The historical average timing of escapement of the entire run is used to estimate winter-run escapement from counts made after May 15. Beginning in 1996, mark-recapture carcass surveys for winter-run Chinook have also been conducted throughout the spawning area.

See Technical Note for the systemwide Central Valley Chinook Salmon indicator for further discussion of methods of estimating escapement.

Redd counts for winter-run Chinook have been carried out with aerial surveys since 1969, although the frequency of flights per year before 1985 was relatively low (averaging around 4 flights per year). The portion of the river above the Highway 44 Bridge was chosen subjectively to represent the upper portion of the river which was most sensitive to improvements in temperature conditions and improved access by adults.

<u>Data Quality and Limitations</u>: See Technical Note for the systemwide Central Valley Chinook Salmon indicator for further discussion of data-quality issues related to escapement estimates.

Longer-Term Science Needs

See Technical Note for the systemwide Central Valley Chinook Salmon indicator for a discussion of science needs related to improving estimates of escapement and juvenile production and to developing improved, quantitative recovery goals.